A supramodal representation of the body surface

Journal Article

http://eprints.bbk.ac.uk/4532

Version: Submitted (Refereed)

Citation:

Visual distortion of body size modulates pain perception

Flavia Mancini[1, 2], Matthew R. Longo[1], Marjolein P. M. Kammers[1], Patrick Haggard[1]

[1]Institute of Cognitive Neuroscience, University College London, London WC1N 3AR, United Kingdom

[2]Department of Psychology, University of Milano-Bicocca, Milano 20126, Italy

Correspondence to: Flavia Mancini, Institute of Cognitive Neuroscience, University College London. 17 Queen Square, London WC1N 3AR, United Kingdom. f.mancini@ucl.ac.uk

Abstract

Pain is a complex subjective experience, that can be shaped by several cognitive, psychological and even contextual variables. For example, simply viewing the body reduces the reported intensity of acute physical pain. We investigated whether this visually induced analgesia can be modulated by the visually depicted size of the stimulated body part. We measured contact heat-pain thresholds, while participants viewed either their own hand or a neutral object, at real size, enlarged, or reduced. Vision of the body was analgesic, increasing heat-pain thresholds by ~ 4°C. Importantly, enlargement of the viewed hand enhanced this analgesia, while looking at a reduced hand decreased it. These results demonstrate that visual distortions of body size modulate sensory components of pain, and reveal a clear functional relation between the perception of pain and the representation of the body.

Introduction

Pain is a frequent but unpleasant experience, with clearly negative impact on well-being. Pain can be caused by peripheral stimuli (e.g., burning one's fingers), by chronic body states (e.g., back pain), or by mechanisms entirely within the brain (e.g., phantom limb pain). The pain generated by a peripheral stimulus varies dramatically across individuals and within individuals across time, so the subjective aspect of pain cannot be ignored (Eisenberger & Lieberman, 2004; Melzack & Wall, 1965). An important element of this subjectivity comes from the wide variety of top-down factors that modulate pain (Chen, Williams, Fitness, & Newton, 2008; Gray & Wegner, 2008). The best-known modulations of pain are cognitive situational factors and complex psychological processes based on expectation and arousal (Wiech, Ploner, & Tracey, 2008), such as placebo effects.

However, simpler perceptual factors also influence pain. For example, just looking at one's own body reduces both reported intensity and neural responses to painful stimuli, compared to viewing a neutral object (Longo, Betti, Aglioti, & Haggard, 2009). This visually induced analgesia demonstrates that acute pain can be modulated by specific features of the visual context. This raises the possibility that manipulating the visual appearance of the body might further modulate pain. Indeed, there is some evidence that the visually-specified size of the body may affect chronic pain in certain clinical populations (Moseley, Parsons, & Spence, 2008; Ramachandran, Brang, & McGeoch, 2009). In this study, we investigated whether manipulating the visually depicted size of the body modulates experimentally-induced pain in healthy participants.

Previous studies of cross-modal pain modulation generally relied on pain intensity ratings. Such ratings reflect both the 'sensory-discriminative' and post-perceptual 'affective-motivational' components of pain (Auvray, Myin, & Spence, 2010; Melzack & Casey, 1968).

We isolated the sensory-discriminative component using contact heat-pain thresholds, which directly measure sensory aspects of acute pain (Yarnitsky, Sprecher, Zaslansky, & Hemli, 1995), while participants viewed their own hand or a neutral object that appeared either visually reduced, at real size, or enlarged. Evidence for an effect of apparent body size on pain perception would have important implications for the development of cognitive therapies for acute pain.

Methods

Participants

Eighteen healthy right-handed volunteers (11 females, mean age 27.1, SD 4.1) participated for payment. Procedures were approved by the UCL ethics committee.

Thermal stimuli

Thermal stimulation of the dorsum of the left hand, just proximal to the knuckle of the index finger (first metacarpal space), was delivered by a 13 mm diameter Peltier-type thermode (NTE-2A, Physitemp Instruments Inc). The probe was held by a mechanical arm to control contact pressure.

Thresholds for heat pain were estimated with the method of limits (Yarnitsky et al., 1995). The probe temperature was increased from the adaptation range (constant 32°C, initially maintained for 20 sec) towards the pain range by 2°C/sec. For safety, maximum temperature was limited to 50°C. Participants pressed a foot pedal with their right foot when they first perceived the stimulation as being painful.

Procedure

We used the mirror box technique (Ramachandran, Rogers-Ramachandran, & Cobb, 1995) to induce the feeling that the participant's right hand, reflected in a mirror aligned with their sagittal plane, was actually a direct view of their stimulated left hand. Participants sat at a table, with the left hand behind the mirror and the right hand in front. The tips of each index finger were 20 cm from the mirror. One group of participants (n = 9) looked into the mirror towards their left hand, and saw the reflection of their right hand, appearing where they felt their left hand to be. For a second group (n = 9), the right hand was occluded by a box, and participants saw the reflection of an approximately hand-sized wooden block placed over it (3 cm over the hand). The visually-specified size of the hand/object was manipulated exchanging three different mirrors (figure 1): a convex mirror giving 2x reduction (0.5x magnification), a normal mirror, and a concave mirror giving 2x magnification. The different visual sizes (reduced, real size, enlarged) were tested in randomised blocks. Because of the length of each block, a between subject design was preferred for the hand vs. object factor to avoid known problems of pain habituation/sensitization.

Familiarisation with the stimulus was first performed over a skin region not used in the main experiment (the centre of the hand dorsum). Next, in each of the three blocks, participants were instructed to look into the mirror and fixate the hand/object continuously. After 10 min of fixation, four heat-pain staircase measurements were obtained from the left hand at 1 min intervals. To avoid perceptual conflict, a fake thermode probe was simultaneously applied to the right hand at the location where the stimulation was felt on the left hand. Three minutes of rest were allowed between blocks.

(figure 1 here)

Three additional measures were collected. First, we administered an established questionnaire (Longo et al., 2009) to ensure that the mirror box induced a compelling visual

illusion of directly viewing the left hand. Second, to check that visual enlargement and reduction of the hand size actually altered represented hand size, participants were asked to judge how big they felt their hand was, using a specially-designed apparatus. Participants adjusted the distance between two visual points to match the distance between the index and little finger knuckles of their left hand. Hand size judgments were made immediately before and after each block. Finally, to assess whether pain thresholds could have changed due to changes in skin temperature, an infrared thermometer was used to measure skin temperature immediately before and after viewing the hand/object.

Results

Questionnaire responses

Agreement or disagreement to each item of the illusion questionnaire was tested by comparing the overall mean score with 0 using t tests. Overall, the mirrors elicited the illusion of viewing one's own left hand when viewing the hand (item 1: $t_8 = 3.41$, $p = 0.009$; item 2: $t_8 = 5.13$, $p = 0.001$; item 3: $t_8 = -12.71$, $p < 0.001$) but not the object (all ps > 0.50).

Three ANOVAs were conducted on the ratings of each item to test the effect of visual size. None of them showed significant visual size effects (item 1: $F_{2,30} = 1.27$, $p = 0.297$, $\eta_p^2 = 0.08$; items 2 and 3: $F < 1$). This indicates that visual size distortion did not influence the illusion of viewing one's hand (figure 2).

(figure 2 here)

Hand size estimates

Differences of the hand size estimates given before and after visual exposure were analysed using repeated measure ANOVA with a between-subjects factor (*visual context*: hand, object) and a within-subjects factor (*visual size*: reduced, real size, enlarged), using the Greenhouse−Geisser correction where appropriate. The ANOVA showed no significant main effect of visual context ($F < 1$), but a significant effect of size ($F_{2,30} = 8.78$, $p = 0.003$, $\eta_p^2 = 0.35$), and a significant interaction ($F_{2,30} = 9.95$, $p = 0.002$, $\eta_p^2 = 0.38$) (figure 3, left panel). Simple effects showed that this interaction emerged because visual size influenced represented hand size when viewing the hand ($F_{2,16} = 13.23$, $p < 0.001$, $\eta_p^2 = 0.62$) but not the object ($F < 1$). Bonferroni follow-up testing in the view-hand condition confirmed that seeing the hand as bigger increased represented hand size ($p = 0.003$), while seeing the hand as smaller shrank it ($p = 0.002$), relative to the control condition. All the comparisons between visual size conditions when viewing the object were non-significant ($ps > 0.30$). These results indicate that the size at which the body was viewed influenced the representation of body size.

Pain thresholds

In the normal mirror condition, viewing the hand at its natural size increased heat-pain thresholds (mean 44.90°C, SE 0.98), in comparison to the view object condition (mean 41.69°C, SE 1.07) ($t_{16} = 2.14$, $p = 0.048$). In other words, merely viewing the hand had an analgesic effect on heat-pain thresholds.

ANOVA on the heat-pain thresholds revealed significant main effects of visual context ($F_{1,16} = 5.20$, $p = 0.037$, $\eta_p^2 = 0.24$), and of visual size ($F_{2,32} = 4.16$, $p = 0.025$, $\eta_p^2 = 0.21$). Crucially, there was a significant interaction between these two factors ($F_{2,32} = 4.58$, $p = 0.018$, $\eta_p^2 = 0.22$). Simple effects analyses showed that visual size modulated pain thresholds when participants saw their hand ($F_{2,16} = 10.18$, $p = 0.001$, $\eta_p^2 = 0.56$), but not the

object ($F < 1$). Bonferroni follow-up tests showed that this arose because visual enlargement of size increased the analgesic effect of viewing the body ($p = 0.032$), whereas visual reduction decreased the analgesic effect ($p = 0.043$), relative to the real size condition (figure 3, right panel). In contrast, visual size of the object had no effect on pain thresholds ($F < 1$).

Because pain thresholds depend on baseline skin temperature, we also investigated whether the different visual conditions induced changes in skin temperature, and thus influenced pain thresholds indirectly. However, no significant main effects or interaction were found ($F < 1$).

(figure 3 here)

Discussion

This study yielded three main findings: (1) Viewing the body versus viewing a neutral object is analgesic with specific effects on sensory-discriminative processing of pain, increasing heat-pain thresholds by about 4°C. (2) The size at which the hand is *viewed* alters the size the hand is *represented* as having. (3) Viewing an enlarged hand increases the analgesic effect of seeing the hand, whereas viewing a reduced hand decreases it. In other words, a stimulus needs to be warmer to be painful when applied to a body part that is seen as bigger than its actual size. Conversely, a stimulus needs to be less warm to produce pain when applied to a body part that is seen as smaller than its actual size.

We thus demonstrate for the first time that vision of the body modulates the 'sensory-discriminative' components of pain experience. Previous studies comparing viewing the body to a neutral object measured pain intensity ratings (Longo et al., 2009). These may be influenced by post-perceptual 'affective-motivational' components of pain (Melzack &

Casey, 1968), such as task demands, response biases, and individual differences (Iannetti, Hughes, Lee, & Mouraux, 2008). Further, recent reviews have questioned how much of 'pain' is truly specific to nociceptive stimulation, and how much is due to general salience and arousal mechanisms (Iannetti & Mouraux, 2010). Therefore, our results using pain thresholds suggest that viewing the body modulates sensory processes specific to pain *perception.*

Our results provide an intriguing contrast with recent psychological studies of empathy for pain. Singer and colleagues (2004) found that empathy for the perceived pain of others influenced affective – but not sensory – aspects of pain, while other studies showed changes in sensory brain areas (Bufalari, Aprile, Avenanti, Di Russo, & Aglioti, 2007) when viewing painful stimulation of others. On the other hand, we previously found that simply viewing the body of another person (a confederate unknown to participants) did not influence either ratings of pain intensity, nor the brain's response to painful stimulation (Longo et al., 2009). One recent study, however, found that viewing photographs of one's partner – but not of a stranger – was analgesic (Master et al., 2009). This suggests that social modulation of pain involves recognition of the identity of the other person. The present results, in contrast, show that analgesic effects of self-perception depend quite directly and proportionately on basic metric features of the visual input, in this case visual size.

Viewing the body was previously reported to improve tactile acuity (Kennett, Taylor-Clarke, & Haggard, 2001). This tactile modulation was further enhanced by visual enlargement. The striking similarity with the present results suggests that visual enhancement of touch and visually induced analgesia may indicate similar mechanisms. For example, visual and multisensory areas that represent one's own body and peripersonal space might modulate networks of inhibitory interneurons in early somatosensory regions. Here, we further showed that reduction of visual hand size increased pain. This bidirectional

modulation rules out explanations based simply on attention, expectations or novelty. Visual distortion of one's own body is unusual in everyday life, so it might plausibly lead to a non-specific arousal effect. However, such non-specific attentional effects should be similar for increased or decreased scales. Our results rather indicate a specific, proportional relation between visual body size and pain perception.

Previous studies demonstrated that alterations of afferent input cause changes in the perceived size of affected body parts (Gandevia & Phegan, 1999). Here, we demonstrate an additional causal relationship in the opposite direction. That is, altering the perceived size of a body part causes changes in pain processing.

Interestingly, a previous study of body size effects on chronic pain reported an apparently opposite effect. Moseley and coworkers (2008) reported that chronic pain ratings and swelling evoked by movement in patients with complex regional pain syndrome (CRPS) increased when viewing the limb enlarged, and decreased when viewing the limb reduced. However, different neurophysiological mechanisms underlie acute and chronic pain (Apkarian, Bushnell, Treede, & Zubieta, 2005; Moseley, Sim, Henry, & Souvlis, 2005). The links between the two mechanisms may be inhibitory, with acute pain inhibiting chronic pain (Baliki, Geha, Fields, & Apkarian, 2010). Further, different therapies relieve the two forms of pain (e.g., Chou & Huffman, 2007; Wiffen, McQuay, Edwards, & Moore, 2005). Importantly, CRPS alters the territory of the affected limb in somatosensory brain regions (Maihofner, Handwerker, Neundorfer, & Birklein, 2003), and involves a complex pattern of disorders, including impaired body image and sense of ownership (e.g., Lewis, Kersten, McCabe, McPherson, & Blake, 2007). These physiological and psychological aspects of CRPS may mediate the visual size effects.

We believe that visual analgesia is not simply based on visual evidence of lack of damage, given that in a threshold experiment participants are aware that damage will never

10

occur. Additionally, we previously found visual analgesia with noxious stimuli that were clearly suprathreshold and entirely invisible (i.e., infrared laser stimuli, Longo et al., 2009).

Finally, our findings cannot be explained by changes in skin temperature or scale-dependence of the mirror box illusion that we used to alternate vision of hand or object at a single spatial location.

In conclusion, we show for the first time that non-informative vision of one's own body has an analgesic effect on pain *perception*. Not only does viewing the body reduce pain, but the specific features of the visual content affect pain processing. Specifically, the analgesic effect is directly proportional to the spatial scale at which the body is seen and felt, with visual enlargement increasing analgesia, and reduction decreasing it. Our results highlight a plastic and flexible link between representation of body size and nociceptive perception. This suggests new possibilities to modulate acute pain cross-modally by manipulating vision of the body. Cognitive therapies that aim to relieve physical pain are generally focused on the painful stimulus itself, e.g. modulating expectations and attention towards pain sources. Here we show that the multisensory context in which pain occurs, in this case the body and its appearance, is also important. Seeing the body enlarged attenuates pain. Looking beyond the painful stimulus, to the body itself, may have novel therapeutic implications.

Figure captions

Figure 1. *Stimuli, apparatus and procedure.*

Figure 2. *Mirrorbox illusion questionnaire.* Item 1 was given in both the view hand and object conditions, items 2 and 3 only in the hand condition. For items 1 and 2, participants rated their agreement using a 7-point Likert scale, +3 indicating "strongly agree" and -3 "strongly disagree". Item 3 required dichotomous responses, after which participants indicated the strength of the feeling that the hand was a right/left hand using a 0-100 scale. Right hand responses were coded positively, left hand responses negatively, yielding scores between -100 (strong left hand) to 100 (strong right hand). Error bars indicate +/- 1 SE.

Figure 3. *Mean changes in hand width estimates (post – pre visual exposure, cm) and heat-pain thresholds (°C), as a function of visual context (hand, object) and visual distortion of size (reduced, real size, enlarged).* Error bars indicate +/- 1 SE.

References

Apkarian, A. V., Bushnell, M. C., Treede, R. D., & Zubieta, J. K. (2005). Human brain mechanisms of pain perception and regulation in health and disease. *European Journal of Pain, 9*, 463-484.

Auvray, M., Myin, E., & Spence, C. (2010). The sensory-discriminative and affective-motivational aspects of pain. *Neuroscience and Biobehavioral Reviews, 34*, 214-223.

Baliki, M. N., Geha, P. Y., Fields, H. L., & Apkarian, A. V. (2010). Predicting value of pain and analgesia: nucleus accumbens response to noxious stimuli changes in the presence of chronic pain. *Neuron, 66*, 149-160.

Bufalari, I., Aprile, T., Avenanti, A., Di Russo, F., & Aglioti, S. M. (2007). Empathy for pain and touch in the human somatosensory cortex. *Cerebral Cortex, 17*, 2553-2561.

Chen, Z., Williams, K. D., Fitness, J., & Newton, N. C. (2008). When hurt will not heal: exploring the capacity to relive social and physical pain. *Psychological Science, 19*, 789-795.

Chou, R., & Huffman, L. H. (2007). Nonpharmacologic therapies for acute and chronic low back pain: a review of the evidence for an American Pain Society/American College of Physicians clinical practice guideline. *Annals of Internal Medicine, 147*, 492-504.

Eisenberger, N. I., & Lieberman, M. D. (2004). Why rejection hurts: a common neural alarm system for physical and social pain. *Trends in Cognitive Sciences, 8*, 294-300.

Gandevia, S. C., & Phegan, C. M. (1999). Perceptual distortions of the human body image produced by local anaesthesia, pain and cutaneous stimulation. *Journal of Physiology, 514 (Pt 2)*, 609-616.

Gray, K., & Wegner, D. M. (2008). The sting of intentional pain. *Psychological Science, 19*, 1260-1262.

Iannetti, G. D., Hughes, N. P., Lee, M. C., & Mouraux, A. (2008). Determinants of laser-evoked EEG responses: pain perception or stimulus saliency? *Journal of Neurophysiology, 100*, 815-828.

Iannetti, G. D., & Mouraux, A. (2010). From the neuromatrix to the pain matrix (and back). *Experimental Brain Research, 205*, 1-12.

Kennett, S., Taylor-Clarke, M., & Haggard, P. (2001). Noninformative vision improves the spatial resolution of touch in humans. *Current Biology, 11*, 1188-1191.

Lewis, J. S., Kersten, P., McCabe, C. S., McPherson, K. M., & Blake, D. R. (2007). Body perception disturbance: a contribution to pain in complex regional pain syndrome (CRPS). *Pain, 133*, 111-119.

Longo, M. R., Betti, V., Aglioti, S. M., & Haggard, P. (2009). Visually induced analgesia: seeing the body reduces pain. *Journal of Neuroscience, 29*, 12125-12130.

Maihofner, C., Handwerker, H. O., Neundorfer, B., & Birklein, F. (2003). Patterns of cortical reorganization in complex regional pain syndrome. *Neurology, 61*, 1707-1715.

Master, S. L., Eisenberger, N. I., Taylor, S. E., Naliboff, B. D., Shirinyan, D., & Lieberman, M. D. (2009). A picture's worth: partner photographs reduce experimentally induced pain. *Psychological Science, 20*, 1316-1318.

Melzack, R., & Casey, K. L. (1968). Sensory, motivational and central control determinants of pain: a new conceptual model. In D. Kenshalo (Ed.), *The skin senses* (pp. 423-439). Springfield, IL: C.C. Thomas.

Melzack, R., & Wall, P. D. (1965). Pain mechanisms: a new theory. *Science, 150*, 971-979.

Moseley, G. L., Parsons, T. J., & Spence, C. (2008). Visual distortion of a limb modulates the pain and swelling evoked by movement. *Current Biology, 18*, R1047-1048.

Moseley, G. L., Sim, D. F., Henry, M. L., & Souvlis, T. (2005). Experimental hand pain delays recognition of the contralateral hand--evidence that acute and chronic pain have opposite effects on information processing? *Brain research. Cognitive brain research, 25*, 188-194.

Ramachandran, V. S., Brang, D., & McGeoch, P. D. (2009). Size reduction using Mirror Visual Feedback (MVF) reduces phantom pain. *Neurocase: The Neural Basis of Cognition, 15*, 357-360.

Ramachandran, V. S., Rogers-Ramachandran, D., & Cobb, S. (1995). Touching the phantom limb. *Nature, 377*, 489-490.

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R. J., & Frith, C. D. (2004). Empathy for pain involves the affective but not sensory components of pain. *Science, 303*, 1157-1162.

Wiech, K., Ploner, M., & Tracey, I. (2008). Neurocognitive aspects of pain perception. *Trends in Cognitive Sciences, 12*, 306-313.

Wiffen, P. J., McQuay, H. J., Edwards, J. E., & Moore, R. A. (2005). Gabapentin for acute and chronic pain. *Cochrane database of systematic reviews, 3*, CD005452.

Yarnitsky, D., Sprecher, E., Zaslansky, R., & Hemli, J. A. (1995). Heat pain thresholds: normative data and repeatability. *Pain, 60*, 329-332.